BEYOND EINSTEIN: From the Big Bang to Black Holes

Constellation X

The Constellation X-Ray Mission

SXT Mirror Technology Progress

Presented by
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Facility Science Team Meeting (FST)
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NASA

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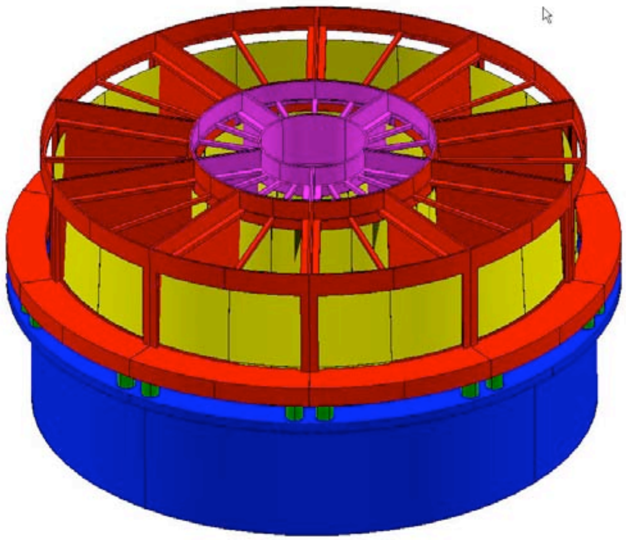
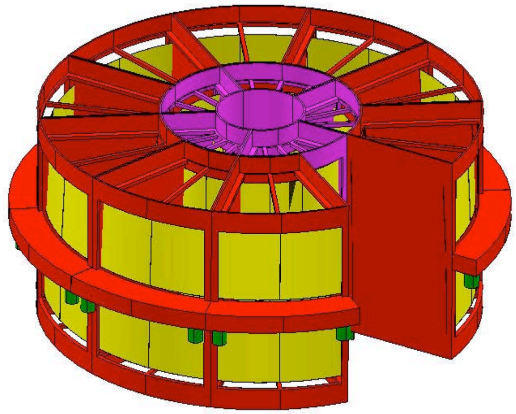
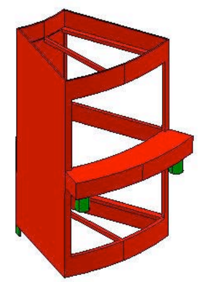
SXT Mirror Assembly



Mirror Assembly



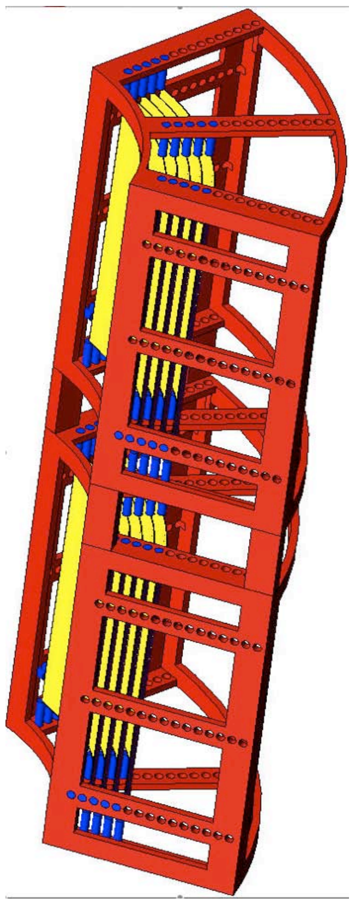


Mirror Module

Mirror Modules

Parabolic Mirror Segments

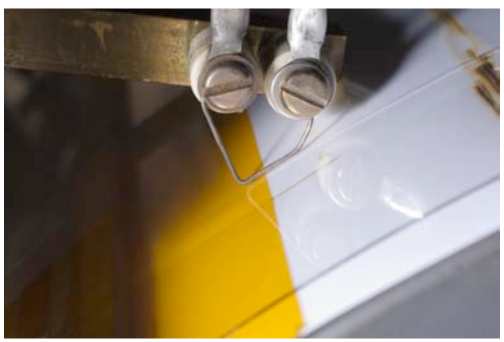
Hyperbolic Mirror Segments



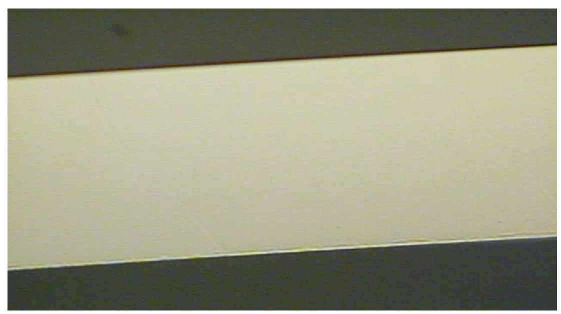
- 5 Identical Inner Modules
  - ID: 300mm
  - OD: 580mm
  - 72° angular span
  - 66 parabolic and 66 hyperbolic mirror segments
- 10 Identical Outer Modules
  - ID: 650mm
  - OD: 1300mm
  - 36° angular span
  - 97 parabolic and 97 hyperbolic mirror segments

Thermal Forming of Glass

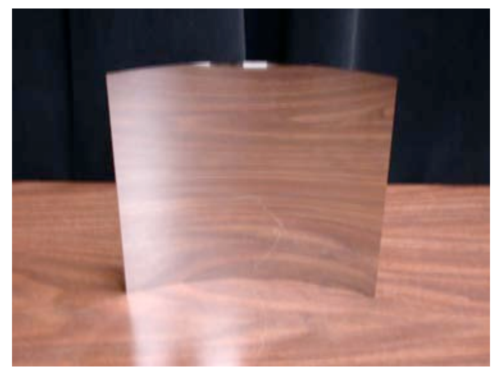
Glass sheet heated to ~600°C to slump under its own weight



Hot wire glass cutter

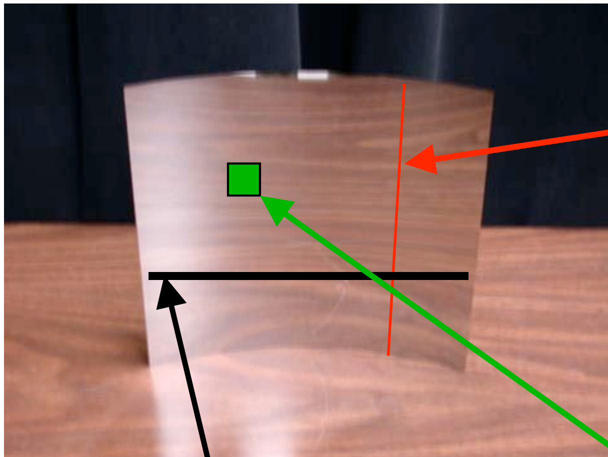


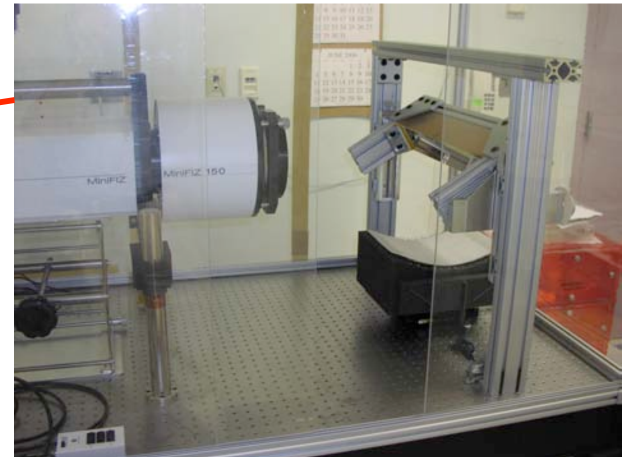
Smooth crack-free edge



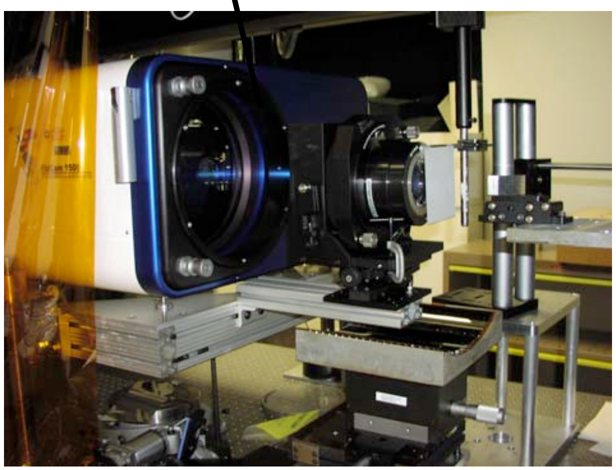
Finished Mirror Segment

Mirror Segment Metrology





Axial Scan



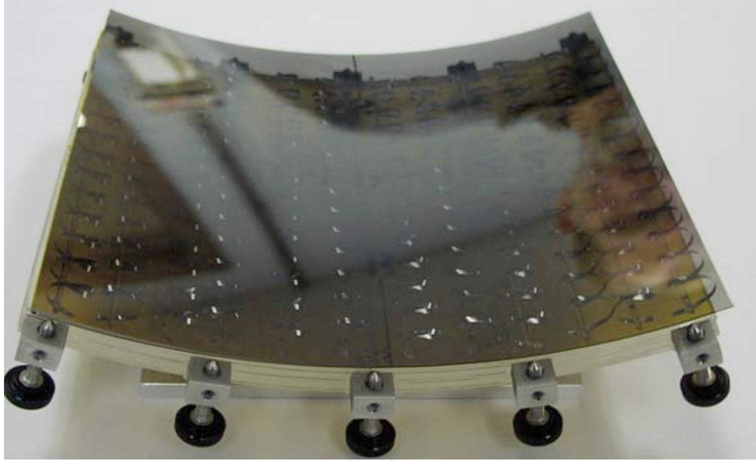
Circular/Azimuthal Scan

Microroughness Measurement

Progress Since December 2005

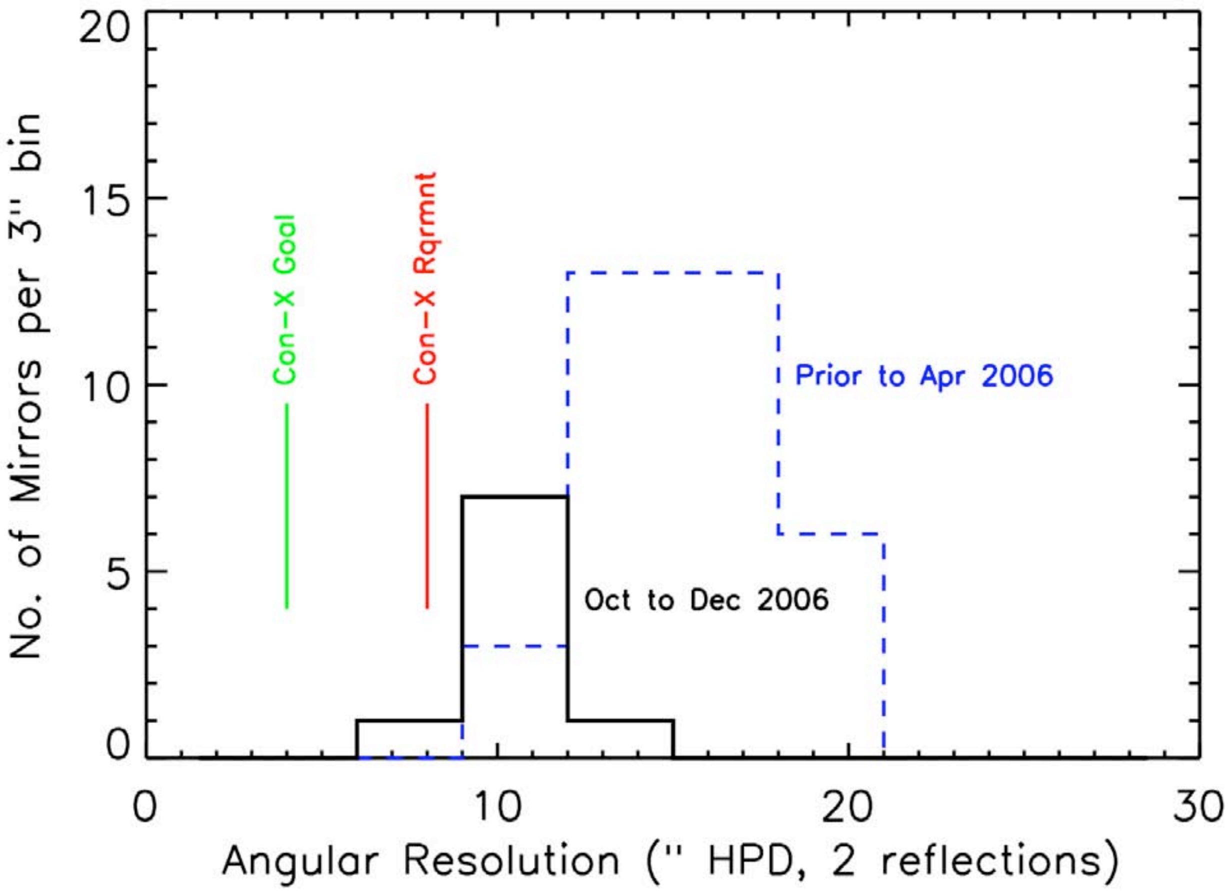
Quantity		Dec 2005 Status	Dec 2006 Status	Dec 2007 Status (Expected)
Radius	Average Radius	Data not repeatable	Data with small statistical error, but large systematic error	Hartmann tests to verify focus rqrmnt; Definitive measurement of circularity; Data systematics may be understood
	Radius Variation (Circularity)	No data available	Central 60% meet rqrmnt	
Cone Angle	Average Cone Angle	Data not repeatable	Data with small statistical error, but large systematic error	
	Cone Angle Variation	No data available	Central 60% meet rqrmnt	
Sag	Average Sag	Data not repeatable	Central 60% meet rqrmnt	Meet rqrmnt
	Sag Variation	Data not repeatable	Central 60% meet rqrmnt; The rest uncertain	Meet rqrmnt
Axial Figure	Low Frequency Figure (200mm-30mm)	Close to meet rqrmnt	Meet rqrmnt	Meet rqrmrnt
	Mid Frequency Figure (30mm-2mm)	Dominating mirror performance	Meet rqrmnt (A factor 2 reduction since December 2005)	Meet rqrmnt
	High Frequency Figure (2mm-0.2mm)	No data available	Equipment commissioned; Data being obtained	Meet rqrmnt or additional processing required
	Microroughness (0.2mm-1um)	Meet rqrmnt	Meet rqrmnt	Meet rqrmnt

Progress since Feb '06



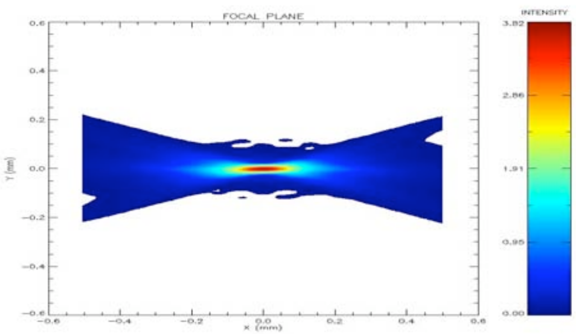
- Implementation of a mirror mattress that has made it possible to measure axial sags with a degree of repeatability
- Measurement of mirror circularity
- Reduction of mid-frequency error by a factor of 2

Comparison of Mirror Quality Distributions



How would the latest mirror perform?

Simulated Image

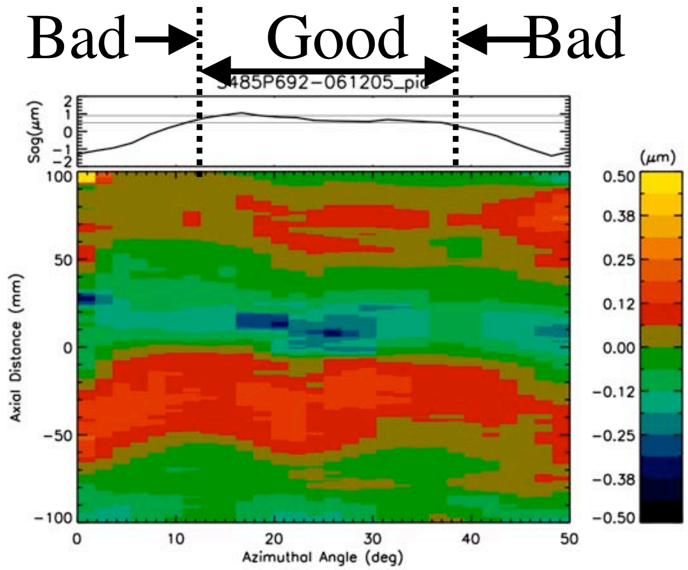


X-ray energy: 1.24 keV

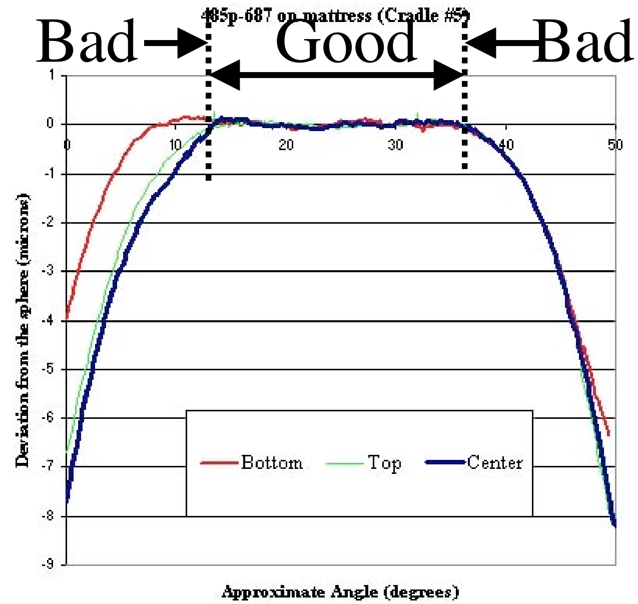
Requirement: 10 arcsecs

	Two-reflection HPD (arcsec)	
	Mirror As Fabricated	Mirror After Removing Mandrel Error
Full Aperture	13.7	10.7
Central 60%	10.6	8.4

What's Wrong with the Typical Mirror Segment?



Axial Measurement



Azimuthal Measurement

The mirror's **apparent** figure degrades near the edges

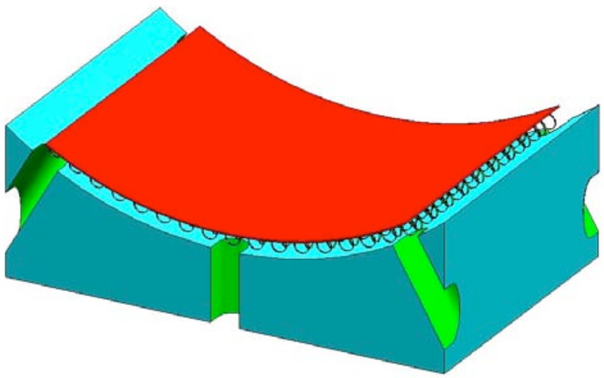
Problems and Solutions

- The sag problem which currently dominates the performance prediction. Three possible causes:
  - Distortion resulting from the mattress: Perform finite element analysis to optimize the construction of the mattress; Conduct many experiments to understand the glass membrane dynamics
  - Residual thermal stress as a result of inadequate annealing: Implement better and optimal annealing process;Practice better thermal engineering of the forming process
  - Coating stress: Reduce coating thickness to the absolute minimum; Reduce the coating speed to the minimum possible
- The mid-frequency problem: clearly caused by particles in the release layer imprinting on the glass
  - Continue to improve the smoothness of the treated mandrel surface
  - Optimize the temperature cycle to reduce imprinting
- The high frequency figure
  - Investigate this band using a newly available Zygo Newview 5000 profiler
  - Perform X-ray tests

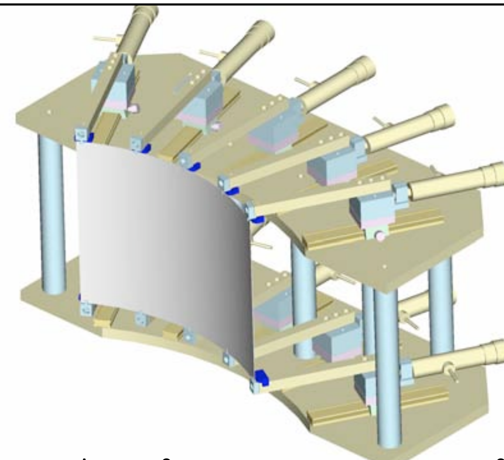
Meet the Four-Fold Challenge of Mirror Alignment and Integration

1. **Many mirror segments to align and integrate**
   - Design and implement a very simple system that can be repeated easily, quickly, and accurately many times
2. **Thin and flexible mirror segments (easy to deform)**
   - Convert each mirror segment into a *de facto* rigid body so that it is easy to handle and transport and all previous experience of aligning and integrating rigid bodies can be utilized
3. **Very little space between adjacent mirrors**
   - Work from inside out so that there is plenty of room available for aligning the current mirror segment
4. **Good mechanical support and vibro-acoustic damping to ensure the stability and survival of the mirror segments**
   - Maximize vibro-acoustic damping through the housing
   - Use only mirror segments that are free of defects

Two Ways of Converting a Flexible Mirror into a De Facto Rigid Body



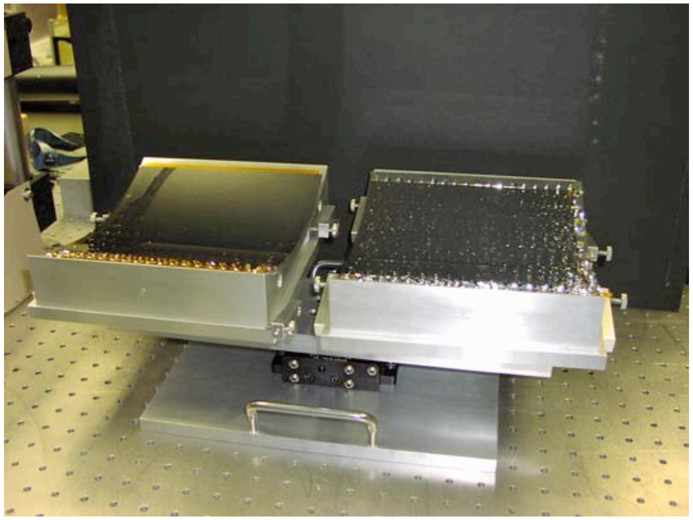
Passive mount with a bed of soft springs



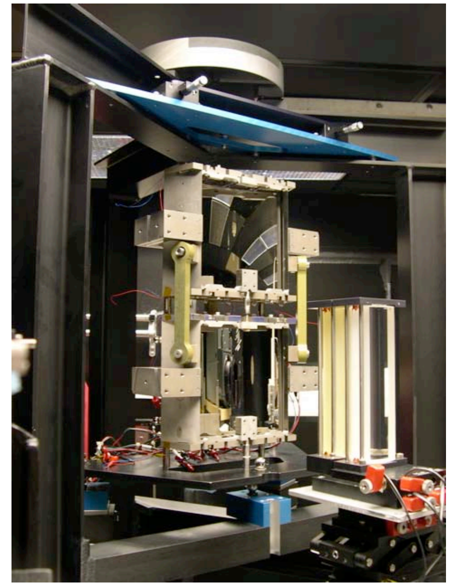
Active mount with precision actuators

- **Passive:** simple and fast, but won't correct figure errors that the mirror might have
- **Active:** complicated and slow, but will correct low order figure errors that the mirror might have

Progress Since December 2005

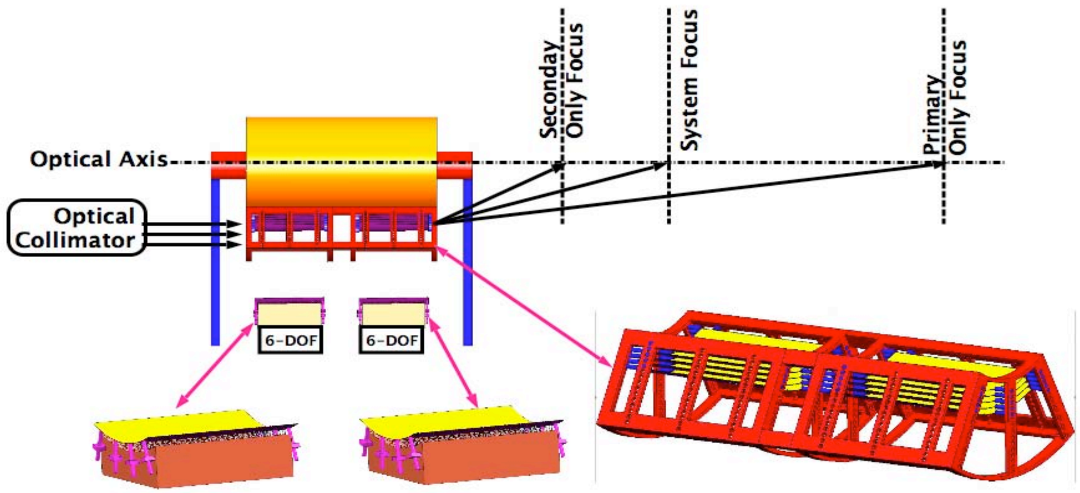


- Achieved good focus quality for both a primary mirror segment and a secondary mirror segment
- Studied both short term (2 hours) and long term (20 hours) stability of the setup



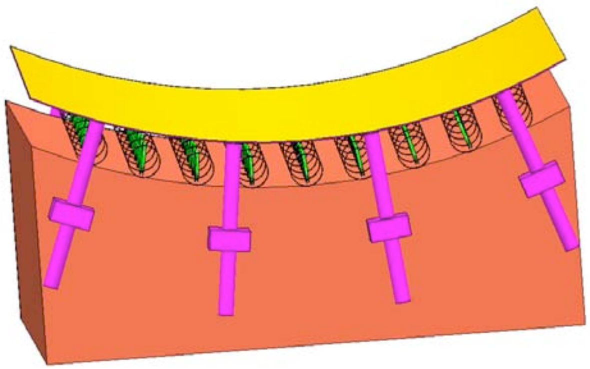
- Achieved high quality mirror segment figure (13.3 arcsec HPD, 2-reflection equivalent)
- The long term stability of platform is in question. Further development is on hold until we can address a variety of engineering issues with the housings and metrology tower

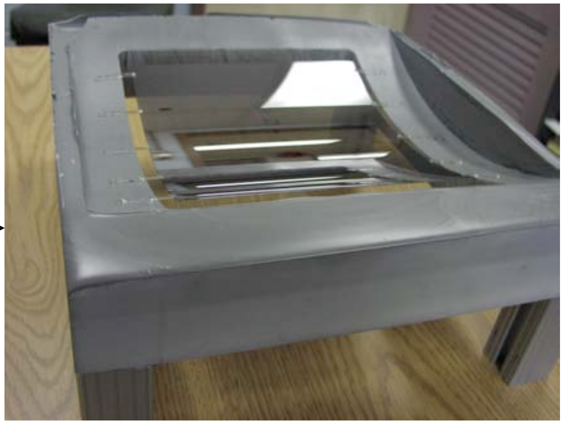
Alignment and Integration



- Align the primary mirror to its own predetermined focus, then transfer it from the temporary mount to the permanent housing
- Align the secondary mirror so that it, together with the primary, forms the best image at the predetermined system focus
- The optimal alignment/integration sequence is: P1, P2, S1, P3, S2, etc.

The most important and elementary operation of the integration process





- The most important and elementary operation of the alignment and integration process is to transfer the mirror segment from its temporary mount to a permanent housing, as shown above
- This operation needs to:
  - Preserve the optical figure of the mirror segment
  - Be highly reliable and repeatable
  - Enable the mirror to survive vibro-acoustic tests

Milestones for Next Two Years

1. Fabrication of mirror segments that meet requirements, using both whole shell and slab forming mandrels
2. Alignment and X-ray tests of *single pairs* in *temporary mounts*; These tests are for the verification of the quality of the mirror segments
3. Alignment and X-ray tests of *single pairs* in a *permanent housing*
4. Alignment/integration and X-ray tests of *multiple pairs* in a *permanent housing*
5. Alignment/integration and X-ray tests of *multiple pairs* in a *flight-like housing;* Vibro-acoustic tests of the same (Maybe in FY09)

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